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THE DEVELOPMENT OF A MOULDED WOOD FIBRE PRODUCT BY DRY-PROCESS MOULDING OF A FIBROUS MAT

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THE DEVELOPMENT OF A MOULDED WOOD FIBRE PRODUCT BY DRY-PROCESS MOULDING OF A FIBROUS MAT

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Ontario Ministry of the Environment

and

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1.0 OBJECTIVES

To demonstrate a dry process, moulded fiberboard technology that could be used to convert discarded wood pallets and similar wood wastes into saleable products.

- To identify and assess wood waste reduction machinery to convert wood pallets to chips.
- To design and fabricate a pallet-tray for the stable transport of tote boxes in the auto industry.
- To produce pallet-trays and mount them on pallets for field testing in the industry.
- To test different types of pallets with trays attached.

2.0 INTRODUCTION

Solid wood waste from manufacturing industries and other sources such as building construction, renovation and transportation has been estimated at up to 1 million tons per year in Ontario. Because of the bulk and form of these wastes, it is becoming increasingly difficult to dispose of solid wood in municipal dumps. Many dumps no longer accept wood, and alternative solutions are not easy to find.

In the auto industry, softwood pallets used for the shipping and handling of parts, present a major waste disposal problem. The volume of wood associated with these pallets is very large and the economics do not favour the reuse of these low cost "one-way" items. However, in relation to many other wood wastes, the auto industry pallet has the advantage of being relatively consistent and free of contamination by other waste materials. This makes the logistics of collection and processing much more attractive in any attempt to find alternate uses.

3.0 BACKGROUND

Moulded wood-fibre products

In 1963, Wayerhaeuser Co. became the first company to manufacture large volumes of moulded wood-fibre doors. The technology developed very slowly, with Masonite Corp. and Jeld Wen Corp. establishing manufacturing facilities in the 1970's to produce similar door products.

It was not until the early 1980's that the term "advanced wood-fibre composite" was recognized. This new product is a wood-fibre-composite containing two or more materials in addition to wood fibres. It was developed to improve mechanical and physical properties such as stiffness, strength, toughness and dimensional stability. With these improved properties researchers began to consider new applications.

The properties of "advanced wood-fibre composites" can be tailored to product requirements. The mechanical and physical properties are controlled by the amount of wood fibres, resins and synthetic reinforcements used as well as the processing parameters applied in the moulding stage. An endless number of shapes and forms can be produced with the proper blend of components.

Wood fibres

Wood fibres remain one of the cheapest raw materials for the production of components and have distinctive characteristics such as heat stability, non-rusting nature and high strength for relatively low weight. The introduction of advanced wood-fibre composites is one of the more significant developments in the long history of the wood industry. It could stop or reverse the loss of traditional wood markets to the plastics and steel industries in such areas as; housing, recreational materials, automobiles, packaging and transportation.

Softwood and hardwood in the form of roundwood, slabwood, forest thinnings and sawmill and factory residues can be used. The resource is first converted to chips which are screened and treated to remove any foreign materials. The chips are steamed under pressure then forced through a narrow gap between rotating discs of a refiner. This separates individual fibres or fibre bundles from the softened wood chips. The wet fibres are then dried with a high velocity hot air source and collected in a cyclone. The wood fibres at this stage are very bulky and require large self unloading storage bins.

Resins (adhesives)

Resin technology for moulding applications is still developing. Phenol formaldehyde resin appears to be the most suitable adhesive for most moulded fibre products. It is widely used in the wood products industry and can offer a wide range of properties. It is relatively inexpensive and can be chemically modified to react with certain reinforcing fibres. A number of specially designed phenol formaldehyde moulding resins have been tested for intricate moulded products.

Reinforcements and additives

Reinforcements provide certain mechanical properties to the composites which are not easy to achieve from wood fibres alone. The most widely used reinforcements in advanced composites are:

- glass fibres
- aromatic polyamide fibres containing para-oriented linkages (Kevlar)
- graphite
- boron

They are available in a variety of forms:

- continuous strands and roving
- chopped fibres
- woven fabrics
- non-woven mats or scrims

Reinforcements can be impregnated with a partially cured resin or thermoplastic resin to improve their mechanical, chemical and physical properties, (commonly called 'prepregs'). Prepregs are widely used in manufacturing of high-performance components. In addition, reinforcements are often sized with a coupling agent. Coupling agents are ingredients that are designed with molecular end groups suitable for bonding to inorganic reinforcements on one end and the organic material on the other end.

From the technical viewpoint of moulding, the main drawback of wood fibres is a lack of fluidity. This fact makes it difficult to mould sharp (low draft angle) and deep profiles. To overcome this, textile fibres can be blended with wood fibres, resin and reinforcement to form a strong drawable mat. Various textile fibres can be used to improve drawability. Included are:

- polyester
- nylon
- orlon
- polypropylene

Of course, many other types of synthetic fibres can be considered if available in a suitable form and at a reasonable price.

Moulding

Since wood fibres are much lower in density relative to other materials such as resins, organic fillers and reinforcements, and since the volume ratio of resin to wood fibres used is normally kept very low for the sake of economics, the moulding mixture has very low fluidity even at elevated temperatures. As a result, compression moulding is probably the best method for moulding wood fibre products. A full understanding of the method, requires an appreciation of many factors such as resin behaviour, ratio of resin to wood fibres, moulding machine, moulds and the parameters affecting the polymerization of resin.

In its simplest form, compression moulding is carried out in the following manner:

- A quantity of thermosetting mixture is placed in the bottom half of an open heated mould which is mounted in a press.

- The press is then closed, bringing the bottom half of the mould against the top half under pressure. As the hot mould halves come together under pressure, the resin begins to soften, facilitating the moulding of the composite.

Elements of the process

The compression moulding process is made up of five major elements:

(1) part design
(2) material selection
(3) mould design and construction
(4) moulding machine
(5) operator

The process must take into account the requirements of the final products and the behaviour of moulding compounds during the pressing stage.

Processing variables

A number of variables, many of them interdependent, play significant roles in the compression moulding process.

(a) moulding mixtures

Moulding mixtures by themselves bring to mind a number of variables such as the formulation of the resin, the characteristics of the various components used, and the ratios and compositions of moulding materials.

(b) temperature and time

Most thermosetting resins will cross link over a wide range of temperature and time. The majority of thermosetting resins must be heated to approximately 300 °F for optimum cure. But it is not necessary to have a complete cure during moulding because further cross linking by residual heat can occur outside the mould. The cure time required depends on the moulding temperature, product thickness, resin characteristics, moisture content of moulding materials, etc. If the temperature is too high, precure may occur and the resin may not have a sufficiently long period of low viscosity for satisfactory moulding. If the temperature is too low, a long cure time is required and thus productivity will be reduced.

(c) breathing and dwell

As part of the condensation polymerization curing process, some thermosetting moulding resins such as phenolic resins give off gaseous products that in combination with the moisture in the wood fibres or additives, produce an internal gas pressure at the elevated temperature of the moulding cycle. Under high pressure, these gases can be contained in the moulded parts until curing is fairly complete; the moulded products then may be removed from the mould without damage if the density is not too high. However, if the moulding cycle is short and the density of the moulded product is high, delaminations, blisters or rupture will occur when the press is opened. To avoid the damage caused by excessive gas pressure, the mould can be opened at some preset times during the process cycle to allow breathing or 'degassing' to occur. The length of time that the mould remains slightly open for degassing is called the 'dwell' and depends on the size and configuration of the moulded object. This step also reduces the cure time in the press because the lower internal gas pressure allows the press to be opened before a full cure is reached.

(d) pressure

The moulding materials with wood fibres are normally low in density before moulding. In order to develop adequate strength properties, pressure is required to compress and consolidate the material. The pressure used should be high enough to consolidate moulding materials during the period of low resin viscosity.

4.0 MATERIALS AND METHODS

4.1 DESIGN AND FABRICATION OF A PALLET-TRAY MOULD

A small 25 x 25 cm (10 x 10 inch) mould was designed and fabricated of aluminum in a local machine shop. This mould (Figure 1) contained the profiles of the full-sized pallet-tray mould, but was more practical for experimentation. The key element of the tray was a series of short ridges, about 1.0 cm high, that were arranged in a rectangular grid designed to "key in" with the base of tote boxes. The design was based on similar plastic units being used in the industry, but with corners omitted from the rectangular sections to provide for the drainage of water.

Tests were conducted on the small mould, using a mouldable "wood fibre" mat, but results showed that the mould was not quite suitable for the process. There were open tears in the moulded specimens because of the severe "drawing" of the mat over the grid ridges. It was concluded that the sides and the ends of the ridges were too steep and that the male and female parts were too closely matched. The mould was lightly remachined to reduce these effects, and subsequent specimens were noticeably improved.

Based on experience from the small mould, a full-sized (142 x 122 cm) pallet-tray mould was designed and fabricated. This design included some additional profile changes in the male mould to further enhance drawability over the ridges. The changes reduced the density of the ridge walls, but not to the extent that strength and durability were significantly diminished.

4.2 SELECTION OF A COMMERCIAL FIBRE MAT

Four commercial, mouldable fibre mats were identified for dry-process moulding. These were being used primarily for the manufacture of moulded quarter panels and other interior trim items for automobiles. The selection of a mat for the pallet-tray studies was based on economic considerations as much as technical qualities. If all mats produced suitable moulded specimens, the choice would come down to the greater business potential. On this basis, Forintek and Fibre Control Inc. opted for a French process offered by Groupe Isoroy of Boulogne, France. The decision was confirmed after Mr. R. McGuire of Fibre Control and Mr. G. Brunette of Forintek visited Isoroy to observe the process and obtain additional details on the technical and economic advantages or disadvantages. Pine and poplar lumber were used to demonstrate the process and provide samples for shipment to Forintek's Ottawa laboratory.

The initial pine and poplar mats were produced under Isoroy's standard procedures. Mat weights were 2.0 and 0.6 kg/m^2. The low weight (thin) mat was used to test the effects of cross-lamination and to increase mat thickness gradually in order to establish the limits of product thickness and density for the pallet-tray moulding.

4.3 TEST SERIES I

Specimens of fibre mat were flat-pressed for 3 minutes at 210°C to produce fibreboard samples for evaluation of strength and stiffness, according to the procedures of Standard SAE J949a (Society of Automotive Engineers). Specimen density was targeted at 810 and 1050 kg/m^3 (50 and 65 lb/ft^3). The mouldability of the mats and the surface quality of the fibreboard was assessed by visual examination of 15 specimens produced with the small mould. These included fibreboards of one, two and three mat plys.

4.4 TEST SERIES II

After meeting Mr. M. Vernois of Isoroy to discuss improvements, a second series of tests was conducted on flat-pressed fibreboards made of a modified fibre mat. This mat had more synthetic fibre and was pre-needled in addition to the normal needling used to interlock the synthetic and wood fibres. Sixty small mats (30 x 30 cm) were obtained in weights of 1.5, 1.7 and 2.0 kg/m^2. Also, the small mould was further modified by reducing the height of the grid ridges on the male portion by 0.60 mm. This reduced the severity of the draw and the density difference between the flat and ridged portions of the moulding. The tests included mats that were sprayed with water on both faces prior to pressing in attempt to make the faces of the fibreboard more dense and fray-resistant. The mouldability of the mats was assessed on the quality of 25 pallet-tray specimens produced with the small mould (Figure 2).

4.5 FULL-SIZED PALLET-TRAY MOULDINGS

A sufficient quantity of the modified mat was ordered from Isoroy for 25 pallet-tray mouldings. These were made with the 142 x 122 cm mould mounted in a large hot press at 215°C (Figure 3). The mats were lightly sprayed with water on both faces and pressed for 3.5 minutes to a thickness of 3.8 mm (0.15 inch) at the flat (base) portions of the moulding. Twelve of these mouldings were trimmed and fixed onto the deck of wooden pallets provided by Fibre Control Inc. After a final coating of paint, the pallets were shipped out for field trials.

4.6 PALLET REDUCTION MACHINERY

Suitable machinery was identified and assessed for the primary reduction of pallets and other wood wastes into refinable wood chips. The report on this machinery is included herewith as Appendix I (also provided with progress report no. 2).

4.7 PALLET TESTING

Three types of pallets were tested in the laboratory according to the procedures of ASTM D1185. Pallets included a standard hardwood pallet with a pallet-tray moulding nailed to deck boards on hardwood stringers; a plywood pallet with a pallet-tray nailed to a 5/8-inch, 5-ply spruce plywood deck on blocks, and a plastic, tote-box pallet produced commercially. Pallet details are provided in Appendix II.

The tests conducted consisted of the following:

. shock load capacity	(D1185 section 10)
. stiffness	(D1185 section 30)
. static load capacity	(D1185 section 6)
. leading-edge impact	(D1185 section 22)

A brief description of each test is given in Appendix III

5.0 RESULTS

5.1 TEST SERIES I

The strength and stiffness of the flat-pressed fibreboard from the initial unmodified "Isoroy" mats are shown in Table 1. For equivalent density the poplar and pine fibreboards were almost equivalent in strength (modulus of rupture - MOR) and stiffness (modulus of elasticity - MOE). On the other hand, there were large differences with respect to the orientation of test specimens. Fibres were preferentially aligned across the mat width, and therefore the stiffness in the cross-mat direction was over 40 percent greater. The cross-mat strength was about 25 percent greater.

The strong directional effect was not conducive to a uniform (two-way) drawing of the mat over the mould. The stiff, cross-mat direction had a much greater tendency to tear. It was anticipated that this problem could be alleviated by more intensive needling of the mat and an increase in the amount of synthetic fiber.

The mouldability of the standard mat was not adequate when attempting to make a moulding of desirable thickness (5.0 mm) and of sufficient density to obtain a non-frayable surface. A mat of at least two-ply thickness was necessary to achieve this, but at this thickness there was too much advance compression at the mould ridges for effective drawing. Such mats would inevitably tear at the ridge ends, where fibre was drawn from three sides. Single mats (20 mm thick) moulded well but had to be pressed to a thickness of 2.5 mm to obtain sufficient density. At this thickness the crown of the grid ridges was very thin (1.3 mm) and vulnerable to damage.

5.2 TEST SERIES II

The initial tests of the modified mat were conducted to determine the minimum fiberboard density required to achieve a MOE of 2500 MPa (Chrysler Motors requirement MS-LD1-32) and to obtain a fray-resistant surface. All mat faces were lightly sprayed with water, as this significantly improved the surface quality of the fibreboard.

The results for flat-pressed boards at 3.3 mm target thickness and 850 to 1200 kg/m^3 density are shown in Figure 4. A density of at least 920 kg/m^3 was required for a minimum MOE of 2500 MPa. For a non-frayable surface, the required density was only slightly lower, at 880 kg/m^3. It was also apparent that the mat modifications were very effective in minimizing the directional effect in terms of stiffness (MOE). The strength (MOR), however, remained higher in the parallel-to-fibre or cross-mat direction (Figure 5).

A single mat of the heaviest weight (2.0 kg/m^2) produced a good moulding when the base (flat) portion was pressed to 3.3 mm thickness (920 kg/m^3 density). Tests on flat-pressed fibreboard of similar density showed that board properties were well within automotive standards for this type of board product (Table 2). Two mats of 1.5 kg/m^2 were excessive and resulted in tearing at the ridge ends. As a result of these tests the final order from Isoroy was for a 2.2 kg/m^2 mat to produce a full-sized pallet-tray moulding of 3.8 mm thickness and 920 kg/m^3 density.

The sharp profiles of the pallet-tray ridges presented unusually severe demands on the drawability of the mat and therefore it was unlikely that a moulding of 5.0 mm thickness could be successfully made without further changes to the mould profile. Nevertheless, the necessary changes envisioned in a new mould would not adversely affect the serviceability of a slightly modified pallet tray. Essentially, the sharp ridge profiles and abrupt ridge ends should be reduced to a more gradual transition.

5.3 FULL-SIZED PALLET-TRAY MOULDINGS

The 25 full-sized moulds (Figure 6) were made to 3.8 mm thickness and 920 kg/m^3 density. Surfaces, with the benefit of water spraying, were non-frayable, but not as hard as they would have been at a 3.3 mm moulding thickness. The extra thickness, however, should make the ridges more durable to rough handling. The results on the pallets sent out for field trials are not expected until the end of 1991.

5.4 PALLET TESTING

The test results on the three types of pallets are given in Table 3. The hardwood pallet was superior in stiffness and static load deflection, but these properties also made it much less resistant to shock loading. The leading-edge impact resistance was only marginally better than that of the other pallets.

The low shock resistance and the heavy weight of the hardwood pallet made the plywood a more favourable alternative to the plastic pallet. The plywood pallet showed better stiffness and static load deflection than plastic, but somewhat lower resistance to shock and leading edge-impact.

The shock load test was the only test that placed stress on the pallet-tray moulding. Each pallet was loaded with 8 tote boxes at 25 lbs. per box, but the moulded pallet-trays remained undamaged in the few test drops required to fail the pallet.

6.0 CONCLUSIONS

- The Isoroy mat-making process can produce dry-process fibreboard mouldings that meet the requirements for certain automotive trim panel substrates.
- The Isoroy mat does not draw easily over severe mould profiles and therefore careful consideration must be given to mould design.
- The wood chips produced from the hogging of auto industry waste pallets are suitable for refining into fibers that could be used in the Isoroy process.
- A plywood-based pallet would make an acceptable alternative to more expensive plastic pallets as platforms for the movement of tote boxes.

Table 1

Strength and Stiffness of Fibreboard
From Unmodified "Isoroy" Fibre Mat

Mat type[1]	Fibreboard Density (kg/m^3)	Strength MOR[2] (MPa)	Stiffness MOE[3] (MPa)	Surface
2-ply Poplar				frayable
para.	817	33.3	2127	
perp.	815	26.2	1452	
2-ply Pine				frayable
para.	808	30.4	1943	
perp.	807	24.5	1304	
2-ply Poplar				solid
para.	1090	77.1	5341	
perp.	1096	61.9	3723	

[1] para: parallel to fibre alignment (cross-mat direction)
perp: perpendicular to fibre alignment (along-mat direction)

[2] MOR: modulus of rupture

[3] MOE: modulus of elasticity

Table 2

Physical and Mechanical Properties of Fibreboard from Modified "Isoroy" Fibre Mat

			Requirement	
Property		Result	Chrysler MS-LD1-32	Ford ESB-M2E16
Thickness	(mm)	3.23	-	-
Density	(kg/m^3)	956	850 ± 80	800 ± 100 (medium density)
Moisture Content	(%)	5.8	3 to 8	3 to 6
Thickness Swell				
2.5 hr. soak	(%)	4.7	-	-
24 hr. soak	(%)	11.9	-	25
Water Absorption				
2.5 hr. soak	(%)	10.4	50 (1.5 hr)	-
24 hr. soak	(%)	28.6	-	50
Expansion				
2.5 hr. soak	(%)	0.09	-	-
24 hr. soak	(%)	0.24	-	0.7
24 hr. 100% rh	(%)	0.24	0.7	-
Contraction Dry After:				
24 hr. soak	(%)	0.71	-	0.7
24 hr. 100% rh	(%)	0.60	0.7	-
Bursting Strength	(kPa/mm)	987	860	880
Bending Strength	(MPa)	-	-	-
parallel	(MPa)	34.6	-	34 - 58
perpendicular	(MPa)	31.5	-	30 - 56
Stiffness	(MPa)	-	2500	
parallel	(MPa)	2821	-	2200-5200
perpendicular	(MPa)	2855	-	1800-3800

[1] Bending strength and stiffness as per SAE J949a - other tests as per SAE J315.

Table 3

Performance of Pallets Subjected to
Mechanical Tests as per ASTM D 1185

		Stiffness		Static Load			
Pallet type	Shock load (1)	Across length (2)	Across Width (2)	End Openings (3)	Side Openings (3)	Leading Edge Impact (4)	Pallet Weight (lbs)
A	3.7	21,182	5,600	0.006	0.005	6.3	129
B	7.3	3,877	3,558	0.023	0.007	5.3	69
C	8.7	2,742	2,502	0.060	0.072	5.6	60

A - Moulded pallet-tray on hardwood pallet (boards on stringers)

B - Moulded pallet-tray on spruce plywood pallet (plywood on blocks)

C - Moulded plastic pallet

Measurements:

(1) Shock load - No. of drops to failure
(2) Stiffness - Load in lbs. for 1-inch deflection at mid-span
(3) Static load - Permanent mid-point deflection (inch) after 1 hour under 2750 lb. load
(4) Leading edge impact - Distance (feet) required to cause failure when loaded pallet collides with fixed forks

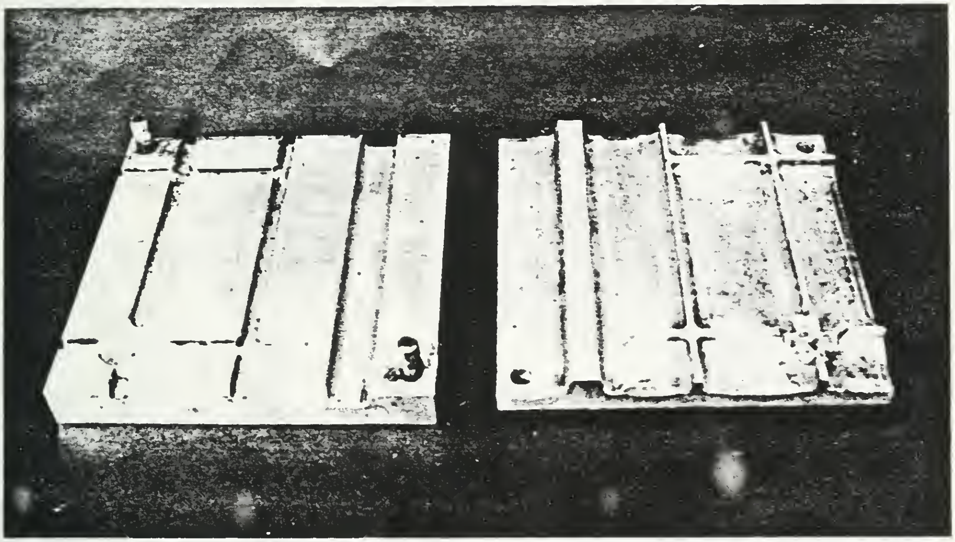


Figure 1. Small pallet-tray mould used for experimentation on mouldability of wood-fibre mat.

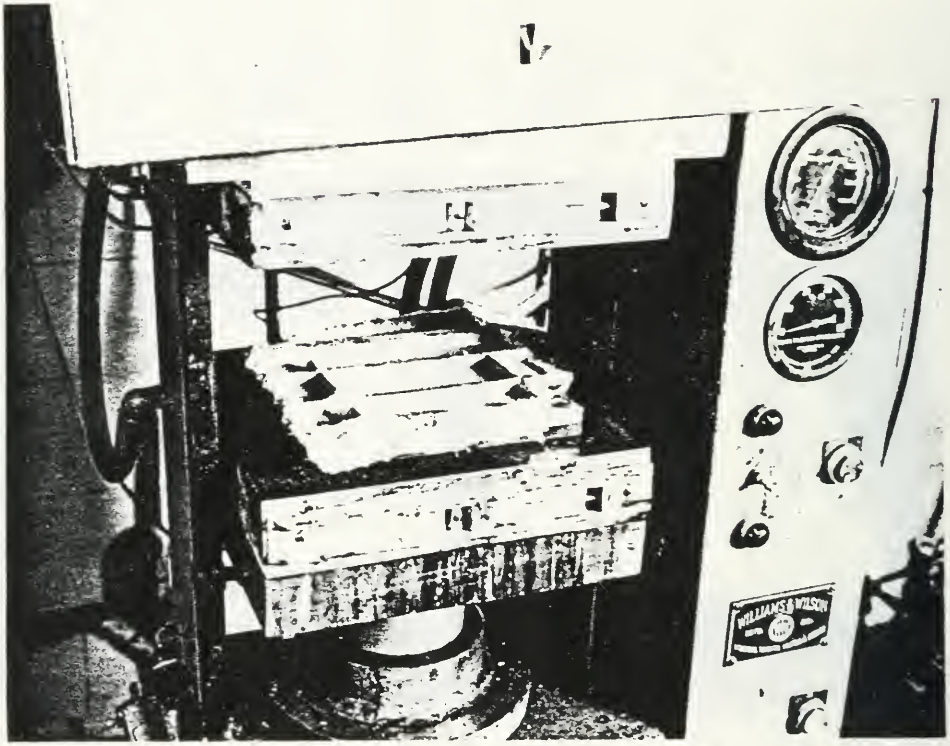


Figure 2. Moulding produced with the small pallet-tray mould in a laboratory hot press

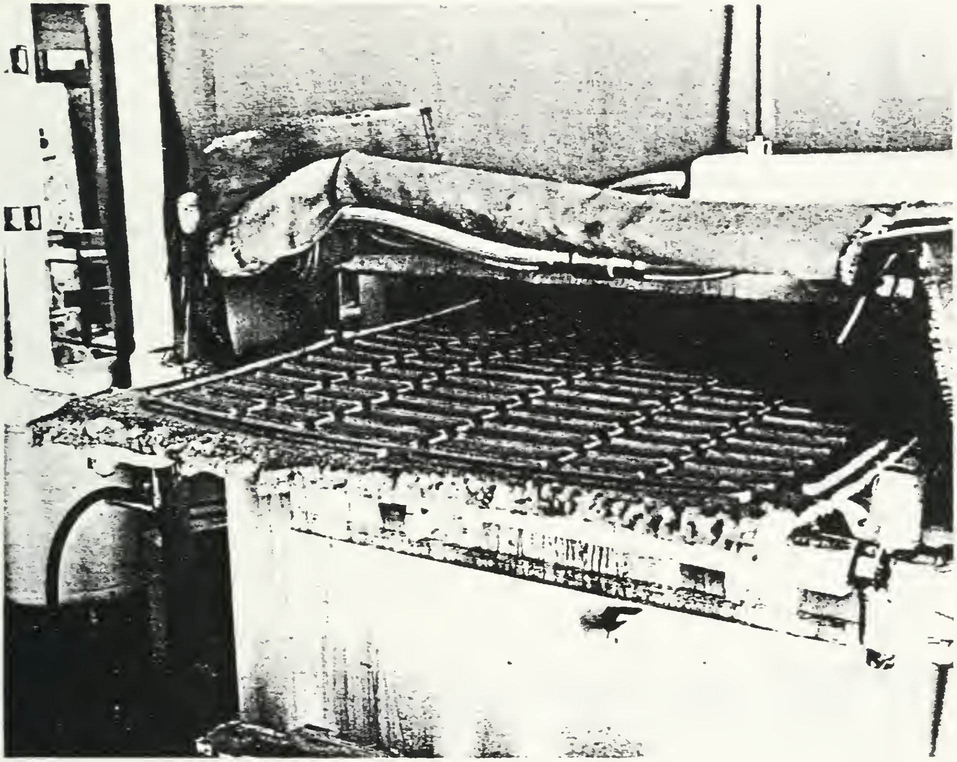


Figure 3. Hot pressing of full-sized pallet-tray mouldings

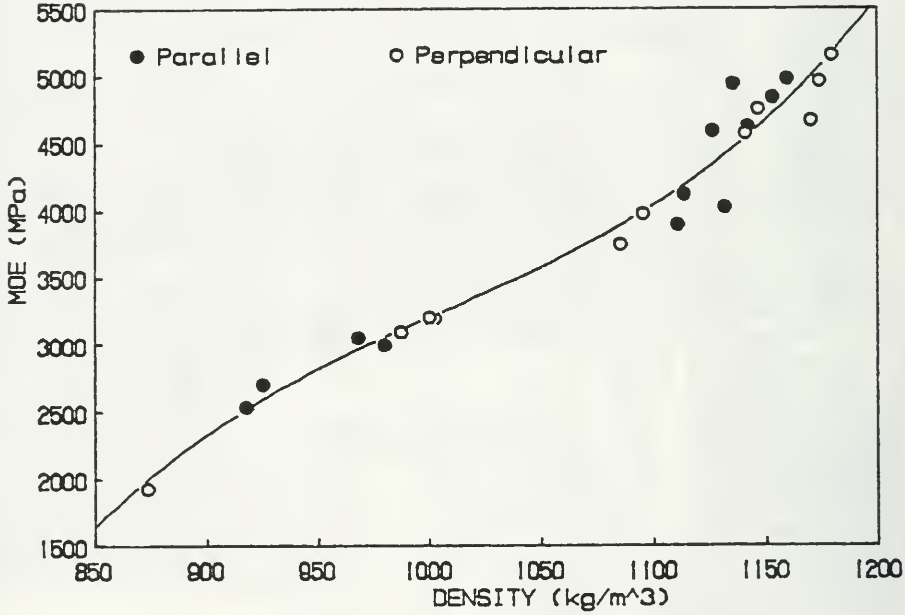


Figure 4. Effect of specimen density on the modulus of elasticity of fibreboard

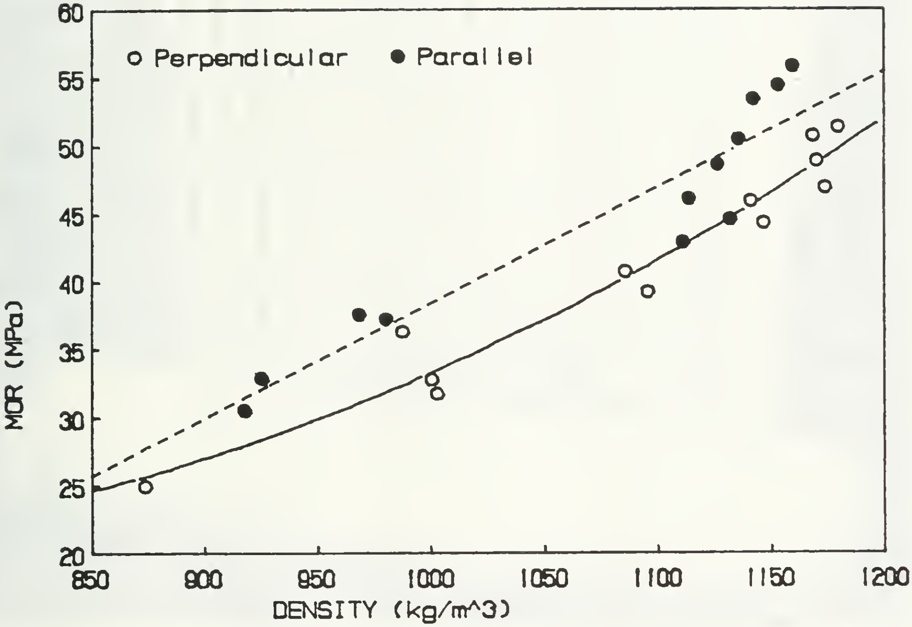


Figure 5. Effect of specimen density on the modulus of rupture of fibreboard

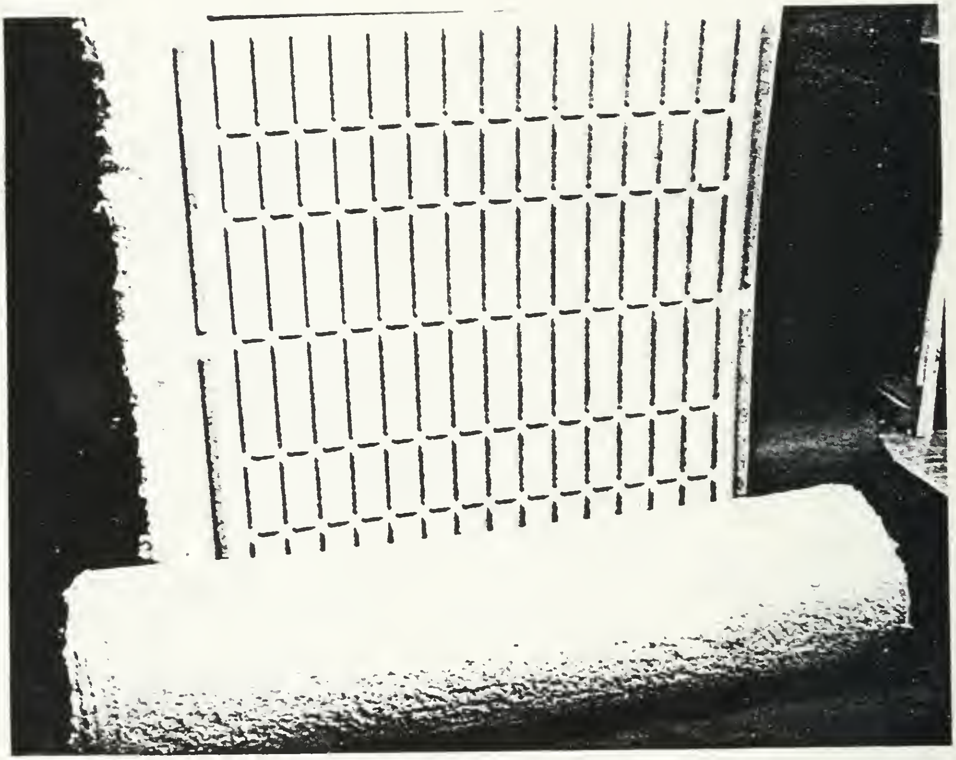


Figure 6. Fibre mat and full-sized pallet-tray moulding obtained for field trials

APPENDIX I

WOODWASTE REDUCTION MACHINERY FOR THE PRODUCTION OF WOOD CHIPS

Woodwaste Reduction Machinery for the Production of Wood Chips

The enormous quantity of used wood pallets and other solid wood wastes generated in southeastern Ontario are creating serious disposal problems. Disposal sites are becoming filled and operators are reluctant to accept large volumes of bulky wood residues such as pallets. To a considerable degree, this problem can be minimized by reducing bulky and awkward wood items to shreds or chips before disposal. Many municipal dumps and landfill sites already require such measures, but a better alternative would be to use the wood fiber as furnish for some types of manufacturing operation or business opportunity. This is already being practiced, although to a very limited extent. Examples include; fibre for mulch, animal bedding, and the manufacture of particleboard, but the price of the fiber is very low because of low-cost alternatives.

The business of producing and selling wood chips or fibres is very attractive. However, if the fibre is further processed to produce a needed product, then the opportunity to convert waste into value should yield both social and financial benefits.

In this regard Fibre Control Inc. of Windsor, Ontario has identified an opportunity to produce moulded wood fibre products such as keyed pallet decks and interior auto door panels to serve a huge regional auto industry. The process as perceived includes the following steps.

- Receive disposable wooden pallets and other suitable wood wastes.
- Reduce bulk wood to chips of suitable size for refining.
- Refine chips in a defibrator to produce wood fibre suitable for production of a dry-process fibre mat.
- Produce fibre mat suitable for compression moulding.
- Mould mats into identified products.

This report concerns the identification of machinery for the primary reduction of pallets into refinable chips. A total of 11 firms were located and contacted for information on their machinery (Table A-1).

The systems available on the market are quite variable in cost and sophistication, but all work on the principle of a rotating hammer mill (hog). All systems must include screens to segregate the desired chip sizes and a mechanism to clean the chips of the metal fasteners used to construct the pallets. Magnetic conveyor pulleys are common.

The type of equipment appropriate for a modest business plan was rated on the following:

- suitable chips for further processing
- good cost/production ratio
- capacity according to need
- simplicity and durability

Three of the identified manufacturers provided suitable equipment within these constraints. Two produce a "tub-type" hog (Viking & Innovator) and the other a drum-type hog (Schutte). Both are available for under $200,000 (with screen and metal separator). The drum-type have a horizontal feed for the pallets and require a ram to force the wood against the hammers. These are designed for pallets and boards and would not be able to accommodate wide, bulky items such as crates and cable spools. The tub-type are gravity fed and depend on the tub rotation and a full tub to maintain optimum feed. Any type of wood waste can be fed into the large tubes (8 to 12 feet diameters). The production rate for 8-foot tubs is about 5 tons/hr. on whole pallets and more if pallets are pre-crushed.

Field Inspections

The Innovator tub-type grinder was inspected at a pallet recycling plant in Toronto (Wood Waste Solutions Canada). This portable unit produced a good quality chip. According to plant workers, it was also far more durable than their previous machine. There were examples of large metal objects going through the system without serious damage or downtime (bolts, rods). The only complaint was occasional objects flying out of the open tub. However, with suitable enclosures this problem could easily be avoided.

Viking Engineering also provides a tub grinder (model 865TG) which is designed to be used in conjunction with their pallet chipper (model 864). The latter can be used on its own and sells for about $65,000 ($50,000 U.S.). However, this equipment is more suitable for the production of mulch and provides no uniformity in the size of particles. The cost and capacity of the total system (864 & 865) are about the same as those of Innovator's tub grinder. The major advantages of Viking's system are that the tub grinder is equipped with screens to control particle size and that the tub is covered, thereby preventing any objects from flying out.

While in the area, we took the opportunity to visit another wood waste recycling plant (WCI Engineered Waste Systems) in Brampton, Ontario. This is a large fixed installation with a two stage breakdown system (primary and secondary shredders) that can process around 20 tons/hr.

Sample bags of the chips were obtained from both installations, although the latter, at $3,000,000 installed would not qualify for consideration.

These chips were later screened into size fractions for comparisons (Table A-2, Figure A-1). No metal was found in either sample.

In the final analysis the Schutte, Viking or Innovator machine would be acceptable, although the operating example of the Innovator process tends to create a greater confidence in this option.

Table A-1. Manufacturers or Suppliers of Woodwaste Reduction Machinery

Company (*Canadian Agent)	**Machines (includes screens, conveyors and metal separator)**
Northfab Systems Inc. to Thomasville, NC 27361 *53 Cowansview Road, Cambridge, Ontario	"Vortex" pallet grinders. Mf. by Vecoplan GmbH; 3 to 4 tons/hr for largest unit; $258,000 full system installed
Schutte Pulverizer Co. Inc. P.O. Box 546 Buffalo, NY 14240-0546	Shutte Hogerizer #56-35 Pallet/scap grinder; 6 tons pallets/hr; $120,000 full system
Viking Engineering and Development Inc. 5750 Main Street N.E. Fridley, MN 55432-5437	Viking/Olathe #864 and #865TG; Portable "tub" type grinder; 5-7 tons pallets/hr;$150,000 system
Innovator Agri Industries Inc. 6675 N. Whiteville Road Rosebush, MI 48878 *120 Weston Street London, Ontario	Innovator ATG 20001 portable "tub" type grinder; 5 tons pallets/hr; $140,000 full system
Montgomery Industries P.O. Box 3687 Jacksonville, FL 32206	Drum type wood hog ER63PM-KC; $220,000 full system installed
WCI Engineered Waste Systems Inc. 69 Eastern Avenue Brampton, Ontario L6W 1X9	WCI urban wood waste processing system; primary and secondary shredders; 20 tons pallets/hr.; $3,000,000 full system
Komar Industries Inc. 4425 Marketing Place Groveport, OH 43125	Auger type machine; requires secondary grinder for proper chip size

Hi-Torque Shredder Co. 230 Sherman Avenue Berkeley Heights, NJ 07922	Pallet shredder plus "particle-izer" to reduce shreds (very slow)
Kernic Equipment Sales Ltd. Century Drive Burlington, Ontario L7L 5J8	Two machines: "Blo Apco" pallet shredder; 955 "Grunendler" grinder for shreds ($350,000 system)
Woodtech Machinery Inc. 26B Chapin Road, P.O. Box 726 Pine Brook, NH 07058	Drum type wood hog with particle screen (hydraulic pusher feed can cause problem with jamming)
Pallmann Maschinenfabrick GmbH Zweibrucken, Feder Republic of Germany	Drum type wood hog with particle screen

Table A-2. Screening Fractions of Chips Produced form Two Wood Pallet Hogs*

Machine or System	Fines Less than #8 Mesh	Particles Between #8, #4 Mesh	Particles Larger than #4 Mesh
Innovator 20001 with large screen	19%	29%	52%
WCI double shredder system	20%	17%	63%

* Chips already once screened to remove over-size.

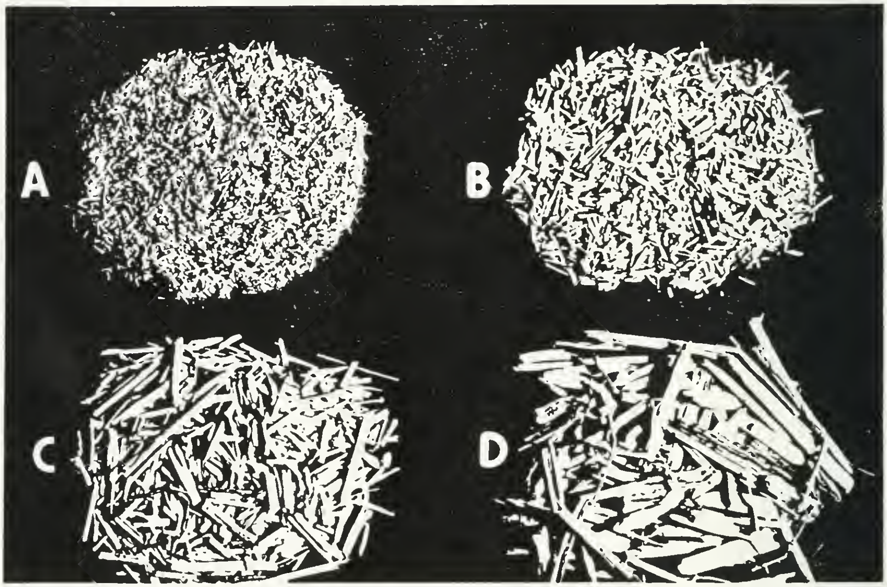


Figure A-1. Screening fractions of particles obtained from pallets hogged in the Innovator tub-type grinder:

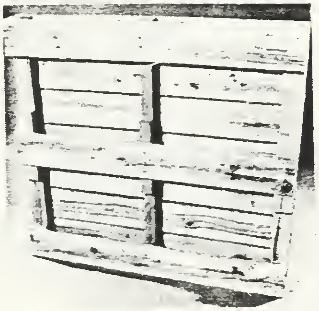
A - Fines:	passing No. 20 mesh screen
B - Fines:	retained on No. 20, passing No. 8 mesh
C - Particles:	passing No. 8, retained on No. 4 mesh
D - Chips:	passing No. 4 mesh

APPENDIX II

TEST PALLET DETAILS

HARDWOOD PALLET
(A)

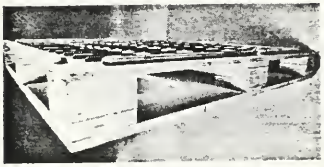
Side



Bottom

Weight	129 lbs
Top deck	boards (7/8 x 5 3/4 x 48 inch)
Bottom deck	boards (7/8 x 5 3/4 x 48 inch)
Stringers	
Outer	3 x 4 x 45 inch
Centre	1 3/4 x 4 x 45 inch
Entry openings	
Ends	4 x 20 inch
Sides	2 1/4 x 10 inch
Fasteners	nails

PLYWOOD PALLET
(B)

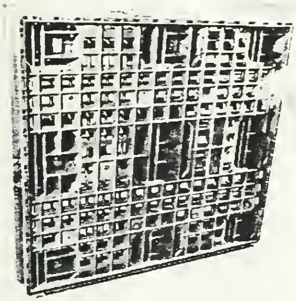


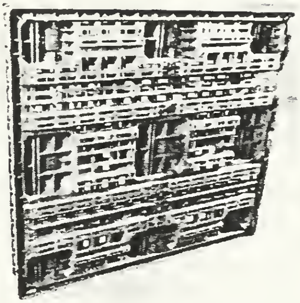
Side

Bottom

Weight	69 lbs
Top deck	5/8" spruce, 5-ply
Bottom deck	3/4" spruce, 6-ply
Blocks	5 x 5 x 3 3/4 inch
Entry Openings	
Ends	3 3/4 x 15 inch
Sides	3 3/4 x 16 1/2 inch
Fasteners	nails

PLASTIC PALLET
(C)


Top

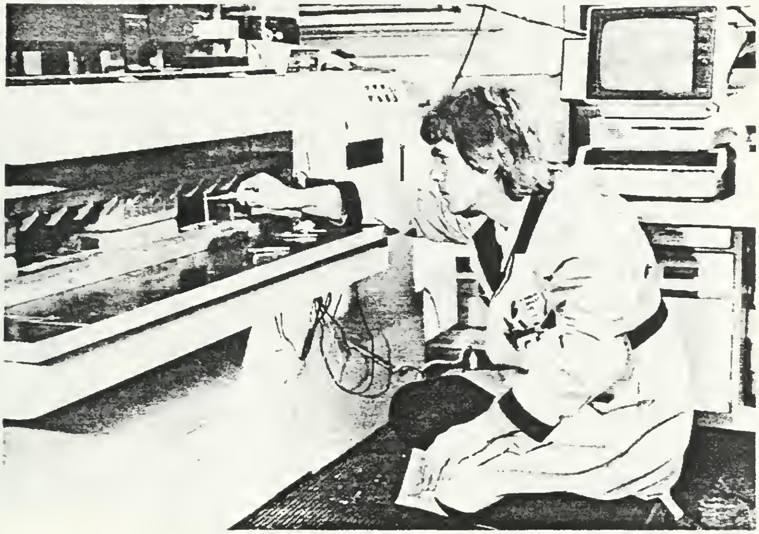

Bottom

Weight	60 lbs
Size	45 x 48 inch
Entry openings	
Ends	2 1/2 x 10 inch
Sides	2 1/2 x 10 inch
Fasteners	none (adhesive bond between top and bottom halves)

APPENDIX III

TEST METHODS

STATIC LOAD CAPACITY
1985 ASTM, D1185, Section 6



6. Significance

6.1 This method is used to measure the resistance of a pallet to static loads during service.

7. Apparatus

7.1 Boards, load application and support, a suitable number, 3.5 in. (90 mm) in actual width, 3.5 in. in actual thickness, and of length at least as great as the longer dimension of the pallet. The boards shall be constructed from lumber dressed four sides and shall have a moisture content no greater than 18%; warp and twist shall not exceed 1.5% of the measured length of the member.

7.2 Bed Compression Testing Machine, large, having a minimum upper limit of 5000 lbf (22 250 N), and platens large enough to cover the decks of the pallet.

7.2.1 A flat and smooth test surface, and a suitable number of weights may replace the large bed compression testing machine.

8. Procedure

8.1 Procedure A -- Place the test pallet on the support boards on the bed of the compression testing machine. Arrange the support boards to simulate the stacking of one pallet load onto another as would be expected in service. If, during service, the tiered pallet is expected to bear upon a flat, smooth surface, the pallet may bear directly onto the lower platen. Place two load application boards on the upper surface of the pallet crosswise to the span at the quarter points of the lengths of the pallet. Apply a load at uniform rate of head movement of 0.1 ± 0.02 in./min (0.041 ± 0.008 mm/s), equal to the design load on the bottom pallet adjusted for long-term loading. Hold this design load for 1 h. Then repeat the test on a second pallet with its bending span perpendicular to the bending span of the first pallet. The following example illustrates the calculation of a test load.

The required test load:

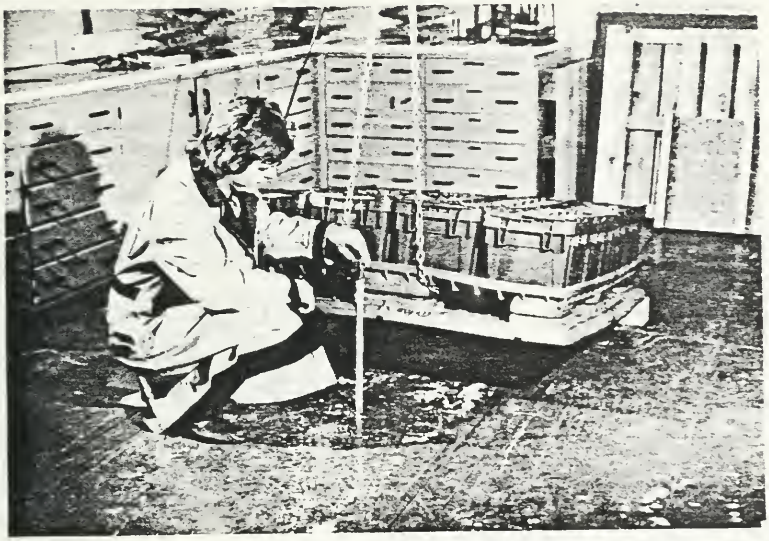
$$w = [(L \times R_t)/R_s] = [(1000 \times 165)/120] = 1375 \text{ lbf}$$

where:

L = design load of pallet (1000 lbf),
w = required test load, lbf,
s = expected duration of pallet loading (1 year),
R_s = ratio of working stress to recommended stress for expected duration of pallet loading (120),
t = duration of test (1 h), and
R_t = ratio of working stress to recommended stress for duration of test (165).

Report height of openings provided for entry (immediately before loading; after load is applied; before load is removed; and after the load has been removed) and any permanent deformation.

SHOCK LOAD CAPACITY
1985 ASTM, D1185, Section 10



10. Significance

10.1 This method is used to measure the resistance of a pallet to shock loadings.

11. Apparatus

11.1 Support Board, one, 3.5 in. (90 mm) in actual width, 3.5 in. (90 mm) in actual thickness, and of length at least as great as the longer dimension of the pallet. The support board shall be constructed from lumber dressed four sides, and shall have a moisture content no greater than 18%; warp and twist shall not exceed 1.5% of the measured length of the member.

11.2 Lifting Device, such as a hoist or block and tackle.

11.3 Quick-Release Mechanism.

11.4 Impact Surface, smooth, level, and unyielding.

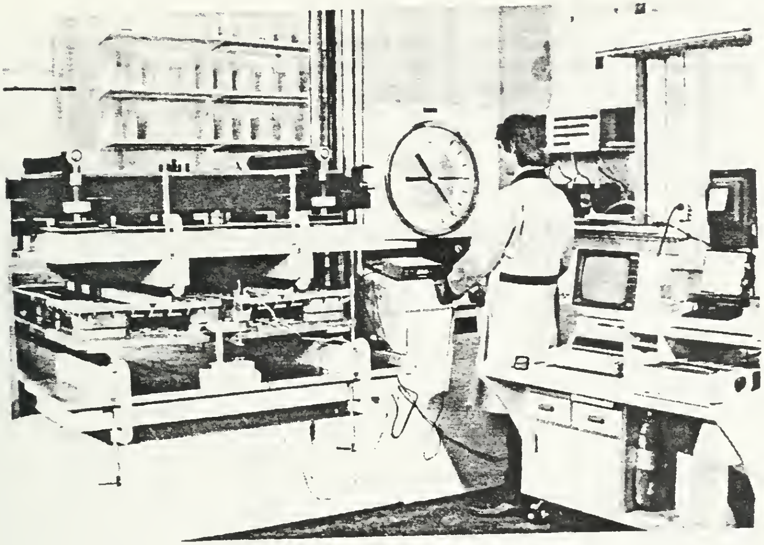
12. Procedure

12.1 Load the test pallet by securing a load, simulating that expected in service, to the top deck of the pallet. Place the support board under one side of the pallet such that the principal axis of the support board is perpendicular to the principal axis of the leading edge-boards. Lift the edge opposite the edge supported by the support board to a height of 6 in. (150 mm) and allow the pallet to fall freely onto the rigid impact surface. Repeat this procedure by placing the support under the opposite side and two opposite ends respectively completing one test cycle. Perform additional test cycles by progressively increasing the free fall height of each additional test cycle by 6 in. (150 mm) to a total free fall height of 24 in. (600 mm). The height of the free fall shall be considered to be that vertical distance between the impact surface and the underside of the edge to be tested. Failure shall be considered to have occurred when the pallet will no longer function with the particular type and size of handling devices intended for use, or when the pallet will no longer support the load.

Note: The load was comprised of 8 tote boxes, each with a grid surface to interlock with the pallet deck. Each box weighed 125 lbs. for a total load of 1000 lbs.

PALLET STIFFNESS

1985 ASTM, D1185, Section 30



30. Significance

30.1 This method is used to measure the overall stiffness of the test pallet both along its length and across its width.

31. Apparatus

31.1 Bed-Compression Testing Machine, large, having a minimum upper limit of 5000 lbf (22 250 N) and platens large enough to cover the decks of the pallet.

31.2 Pipes, four, straight steel support and load-bearing 2 3/8 in. (60 mm) in outside diameter, and of a length at least as great as the longer dimension of the pallet.

31.3 Load Spreaders, plywood, four, 3/4 by 4 in. (19 by 102 mm), of a length equal to the length of the support and load-bearing pipes.

32. Procedure

32.1 Place the test pallet on the bed of the compression testing machine. Place two straight steel-support pipes, extending across the full width of the span, under the bottom deck of the pallet parallel to and 2 in. (51 mm) from the ends of the pallet. Place two identical load-bearing pipes crosswise on the upper surface of the pallet at the quarter points of the span.

32.2 Place the load spreaders between the support and load-bearing pipes and the platens of the testing machine. Apply a 500-lbf (2.2 kN) load to the pallet through the upper load-bearing pipes and fix the spherical head (if applicable). Apply a suitable load to the pallet (minimum 2000 lbf (8.9 kN)) through the upper load-bearing pipes at a uniform rate of head movement of 0.2 ± 0.02 in./min (0.083 ± 0.008 mm/s). Hold this preload for 60 s and reduce by 1000 lbf (4450 N) at a uniform rate of head movement of 0.2 ± 0.02 in/min. Place and zero a micrometer dial under each outside edge of the pallet at the midpoint of the span. Reapply the 1000-lbf load at a uniform rate of head movement of 0.1 ± 0.02 in./min (0.041 ± 0.008 mm/s) simultaneously recording the center span deflection of each outside edge at each 100-lbf (445-N) increase of load.

32.3 Perform the above-described tests across two perpendicular spans of the same pallet. Perform the first test along the length of the pallet. Rotate the pallet 90° and repeat the test across the width of the pallet.